



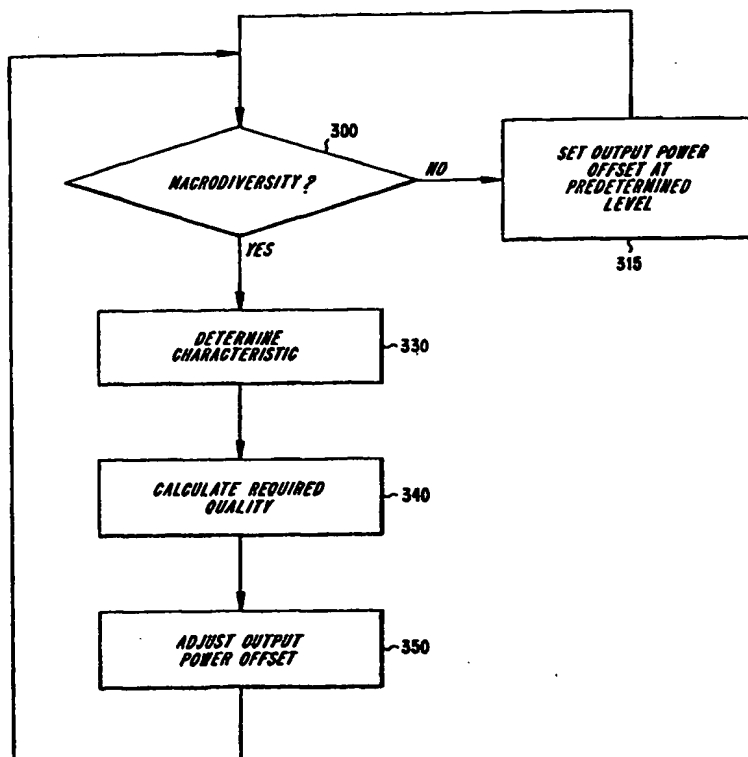
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: METHOD FOR PROTECTING POWER CONTROL COMMANDS USED FOR UPLINK POWER CONTROL

## (57) Abstract

A method adjusts the output power offset between a first signal and a second signal transmitted from a base station to a remote station in a communication system including at least one base station and at least one remote station. The first signal may be a power control command for controlling the power of signals transmitted uplink from the remote station to the base station, and the second signal may be downlink information. A determination is made whether the remote station is in macrodiversity, i.e., receiving substantially the same signal simultaneously from more than one base station, and the output power offset between the first and second signals is adjusted based on this determination. The output power offset may be set at a first level if the remote station is in macrodiversity and at a second level if the remote station is not in macrodiversity. Alternately, whether or not the remote station is in macrodiversity, the output power offset may be adjusted based on a required quality calculated from a determined characteristic of a signal.



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## METHOD FOR PROTECTING POWER CONTROL COMMANDS USED FOR UPLINK POWER CONTROL

### BACKGROUND

5        This invention relates to a method for protecting power control commands used for uplink power control in telecommunication systems, in particular telecommunication systems employing soft handover.

      Good transmit power control methods can be important to communication systems having many simultaneous transmitters because such methods reduce the mutual  
10 interference of such transmitters. For example, transmit power control is necessary to obtain high system capacity in communication systems that use code division multiple access (CDMA). This is important for the uplink, i.e., for transmissions from a remote terminal to the network, e.g., a base station, as well as for the downlink, i.e., for transmissions from the base stations to a remote station. Uplinks and downlinks are also  
15 sometimes referred to as reverse links and forward links, respectively.

      The need for transmit power control in the uplink is recognized in current CDMA cellular systems. Uplink power control according to the TIA/EIA/IS-95-A standard is provided by a closed-loop method, in which a base station measures the strength of a  
20 signal received from a remote station and then transmits one power control bit to the remote station every 1.25 milliseconds. Based on the power control bit, the remote station increases or decreases its transmit (uplink) power by a predetermined amount.

      The need for transmit power control for the downlink has been deemed less important in current cellular and other CDMA communication systems. However, in the future it is expected that more resources will be required in the downlink, compared to the  
25 uplink, due, e.g., to the anticipated increase of Internet services. Thus, it becomes increasingly important to improve the downlink performance.

      An important feature of CDMA cellular systems according to the IS-95-A standard is "soft handover" in which a remote station, e.g., a mobile station, moving out of the range of one base station is allocated a new traffic channel from a more  
30 suitable base station. The process is usually initiated by the mobile station when the

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received signal from a particular base station degrades below a predetermined threshold. The mobile station observes the strength of the pilot (downlink) channel from neighboring base stations and decides which base station is transmitting signals that are received with the highest signal strength. Then, the mobile station requests a new traffic  
5 channel from that base station. The new traffic channel is then used with the existing traffic channel in a space diversity mode called "macrodiversity".

FIG. 1 illustrates a communication system in macrodiversity. The communication system includes a mobile station (MS) and two base stations (BS1 and BS2). The MS receives substantially the same signal simultaneously from BS1 and BS2. As can be seen  
10 from FIG. 1, uplink (UL) data and downlink (DL) power control commands are transmitted in the uplink, i.e., from the MS to BS1 and BS2. The DL power control commands control the power with which information is transmitted from BS1 and BS2 to the MS. In a similar manner, downlink (DL) data and uplink (UL) power control  
15 commands are transmitted in the downlink channel, i.e., from BS1 and BS2 to the MS. The UL commands control the power with which signals are transmitted from the MS to BS1 and BS2. All the information transmitted between the MS and the BS1 and BS2 is the same, except the UL power control commands that are sent on the downlink channels. The UL power control commands are BS-specific, i.e., each base station transmits an  
20 independent uplink power control command indicating that the MS should increase or decrease transmission power. For example, BS1 may transmit a "1" bit or give some other indication that the MS should decrease transmission power, and BS2 may transmit a "0" bit or give some other indication that the MS should increase transmission power.

The performance of a CDMA communication system is very dependent on the performance of fast power control, i.e., uplink and downlink power control as described  
25 above, as well as on the performance of soft handover. Further, fast power control and soft handover are highly interdependent. For instance, if the handover decision is based on the quality of the uplink channel, e.g., the uplink carrier to interference ratio (C/I), instead of the received signal strength, the gain between BS1 and BS2 may differ significantly. This may cause problems in the uplink power control.

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A technique has been proposed to protect the integrity of, i.e., ensure the effectiveness and quality of, downlink power control commands during macrodiversity in a commonly assigned co-pending Provisional U.S. Patent Application No. 60/069,607, filed December 15, 1997, entitled "Modified Downlink Power Control During Macrodiversity". According to this technique, the rate at which downlink power control commands are transmitted may be reduced during macrodiversity. Also, the same power control commands may be repeated, encoded more heavily, and/or made base-station-specific during macrodiversity. This improves the accuracy with which the downlink power control commands are received, ensuring efficient power control.

Downlink performance may be improved by introducing power splitting during macrodiversity, i.e., modifying the transmission powers of the base stations so that they are not equally large. However, this may affect the uplink power control.

To protect the uplink power control commands, i.e., to ensure that the uplink power control commands are accurately received, the uplink power control bits are usually transmitted with a fixed output power or a fixed output power offset that is higher than the output power of the downlink information bits. This can be better understood with reference to FIG. 2, which illustrates the output powers that the uplink power control bits and the downlink information bits are transmitted with in downlink slots. Five slots are shown for illustrative purposes. During each slot, one or more uplink power control (PC) bits and downlink information bits are transmitted. As can be seen from FIG. 2, there is an offset in output power between the PC bits and the downlink information. The PC bits are assigned more output power than the downlink information bits, to ensure that the PC bits are accurately received.

For example, as disclosed in "Personal Station-Base Station Compatibility Requirements for 1.8 to 2.0 GHz Code Division Multiple Access (CDMA) Personal Communications Systems", ANSI J-STD-008, March 1995, pp. 3-15 to 3-17, for Rate Set 1, each uplink power control bit is transmitted with an energy not less than  $E_b$ , i.e., the energy of a downlink information bit, whereas for Rate Set 2, each uplink power control is transmitted with energy not less than  $3E_b/4$ . According to another approach, the uplink power control bits are assigned an energy equal to  $2 E_b$ , and changes in pathloss and

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interference are reacted to at a pace that equals the command rate of the downlink power control.

Yet another approach uses the uplink power control commands, transmitted in the downlink channel at a fixed rate and known output power, to estimate the forward traffic power. This approach is described in S. C. Bang and Y Han, "Performance of a Fast Forward Power Control Using Power Control Bits for the Reverse Power Control as Power Measurements in DS-CDMA System", Proc. CIC-97, pp. 42-46.

In all of these approaches, either the offset in output power between the uplink power control bits and the downlink information bits is fixed, or the output power of the uplink power control bits is fixed. This becomes a problem when the MS enters macrodiversity or may result in a waste of capacity.

The uplink power control commands sent from BS1 and BS2 may differ significantly in quality (a 10 dB difference is not unlikely). Thus, the uplink power control commands from one BS may have a large error probability. However, the MS listens to the uplink power control commands from all BSs that it is connected to and increases its output power only if all the uplink commands from all the BSs indicate that the MS should increase its output power. Otherwise, the MS decreases its output power. Thus, in some cases the uplink power control commands from a certain base station may be lost. The benefits of soft handover in reducing interference between base station transmissions are then not realized and/or the quality is reduced.

This problem is made worse when new soft handover criteria are introduced, e.g., uplink C/I measurements, and when downlink power splitting schemes are introduced.

To ensure that each uplink power control command is acted upon, the power control bits may be assigned so much output power that a high quality is always achieved. However, this would result in a waste of capacity if the same fixed output power offset between the uplink power control bits and the downlink information or the same fixed output power for the uplink power control bits is always used.

There is thus a need for a technique for protecting uplink power control commands by adjusting the output power offset between the uplink power control commands and the downlink information during macrodiversity.

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**SUMMARY**

It is therefore an object of the present invention to provide a variable offset between the output power used for an uplink power control command and downlink information transmitted in a downlink channel.

5        According to the invention, these and other objects are met by a method for adjusting the output power offset between a first signal and a second signal transmitted from a base station to a remote station in a communication system including at least one remote station and at least one base station. According to exemplary embodiments, the first signal is a power control command for controlling the power of signals transmitted  
10        uplink from the remote station to the base station, and the second signal is downlink information.

      According to a first embodiment, a determination is made whether the remote station receives substantially the same signal simultaneously from more than one base station. If so, the output power offset is set to a first level. If the remote station does not  
15        receive the same signal simultaneously from more than one base station, the output power offset is set to a second level.

      According to a second embodiment, if the remote station does not receive the same signal simultaneously from more than one base station, the output power offset between the uplink power control command and the downlink information is set to a  
20        predetermined level or not adjusted. Otherwise, a characteristic of a signal is determined for each base station, the required quality of the uplink power control command is calculated for each base station based on the determined characteristic, and the output power offset between the uplink power control command and the downlink information is adjusted for each base station based on the required quality.

25        According to a third embodiment, the required quality of the uplink power control command is calculated based on the determined characteristic, and the output power offset between the uplink power control command and the downlink information is adjusted based on the required quality, whether or not the remote station receives the same signal simultaneously from more than one base station.

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**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 illustrates a communication system in macrodiversity;

FIG. 2 illustrates a typical slot structure of downlink channel data; and

FIGS. 3A-3C illustrate methods for adjusting an output power offset between first  
5 and second signals transmitted from a base station to a remote station.

The invention will now be described in more detail with reference to exemplary  
embodiments and the accompanying drawings.

**DETAILED DESCRIPTION**

10 It should be understood that the following description, while indicating preferred  
embodiments of the invention, is given by way of illustration only since various changes  
and modifications within the scope of the invention will become apparent to those skilled  
in the art.

According to exemplary embodiments, a method is provided for adjusting the  
15 energy offset between first and second signals transmitted from a base station to a remote  
station. As an example, the following description is directed to an output power offset  
between uplink power control commands and downlink information.

According to a first embodiment, the output power offset is set at a first level  
when the remote station is not in macrodiversity, i.e., when the remote station is not  
20 receiving the same signal simultaneously from more than one base station, and at a  
second level when the remote station is in macrodiversity. The first and second levels  
can be predetermined as desired. The second level can be set higher than the first level,  
to ensure that the uplink power control commands are received with a high quality during  
macrodiversity.

25 FIG. 3A illustrates a method for adjusting the output power offset between an  
uplink power control command and downlink information according to a first  
embodiment. The method begins at step 300 at which a determination is made whether  
the remote station is in macrodiversity. If the remote station is not in macrodiversity, the  
output power offset between the uplink power control command and downlink  
30 information is set to a first level at step 310. If the remote station is in macrodiversity,

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the output power offset between the uplink power control command and downlink information, for each base station, is set to a second level at step 320. From steps 310 and 320, the method returns to step 300, and the process is repeated.

The method according to the first embodiment is simple and effective. This method can be refined by adjusting the energy offset during macrodiversity.

According to a second embodiment, the output power offset is adjusted during macrodiversity based on a required quality of the uplink power control command calculated from a determined characteristic of a signal. The characteristic may, for example, be the downlink interference and/or gain which may be measured at the remote station and reported to each base station. The characteristic may also be the downlink quality, e.g., the carrier to interference ratio (C/I), of a downlink channel with a known downlink output power, which may be measured at the remote station and reported to each base station.

It may be possible to measure the uplink signal and, based on that measurement, control the downlink power control. This is described, for example, in U.S. Patent Application No. 08/880,746, filed June 23, 1997. In order to reduce signalling, uplink measurements, e.g., uplink received power or uplink C/I, made at each base station can also be used as the characteristic for calculating the required quality for uplink power commands.

For illustrative purposes, the following description is directed to the use of downlink C/I and a known downlink power level for uplink power control.

The measured carrier to interference ratio on the downlink (pilot)

channel  $\left. \frac{C}{I} \right|_{pilot}$  is defined as:

$$\left. \frac{C}{I} \right|_{pilot} = \frac{P_{pilot} \cdot g}{I_{tot} - (P_{pilot} \cdot g)} = \frac{P_{pilot} \cdot \frac{g}{I_{tot}}}{1 - (P_{pilot} \cdot \frac{g}{I_{tot}})} \quad (1)$$

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where  $P_{pilot}$  is a known downlink output power level,  $I_{tot}$  is the total received power level at the remote station, e.g., a mobile station, including thermal noise, and  $g$  is the gain between the mobile station and a particular base station. Using a similar notation, the

required quality of the uplink power control command  $\left. \frac{C}{I} \right|_{pc}$  can be written as:

$$\left. \frac{C}{I} \right|_{pc} = \frac{P_{pc} \cdot g}{I_{tot} - \alpha(P_{pc} \cdot g)} = \frac{P_{pc} \cdot \frac{g}{I_{tot}}}{1 - \alpha(P_{pc} \cdot \frac{g}{I_{tot}})} \quad (2)$$

- 5 where  $\alpha$  is the downlink orthogonality factor, and  $P_{pc}$  is the required output power of the uplink power control command.

Setting  $g/I_{tot} = \beta$ , Equation 1 can be rewritten as:

$$\left. \frac{C}{I} \right|_{pilot} = \frac{P_{pilot} \cdot \beta}{1 - (P_{pilot} \cdot \beta)} \quad (3)$$

After some calculations, it can be seen that:

$$\beta = \frac{\left. \frac{C}{I} \right|_{pilot}}{P_{pilot} \cdot \left( 1 + \left. \frac{C}{I} \right|_{pilot} \right)} \quad (4)$$

Equation 2 can also be rewritten by using  $\beta$  as:

$$\left. \frac{C}{I} \right|_{pc} = \frac{P_{pc} \cdot \beta}{1 - \alpha(P_{pc} \cdot \beta)} \quad (5)$$

10

After some calculations,  $P_{pc}$  can be extracted as:

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$$P_{pc} = \frac{\left. \frac{C}{I} \right|_{pc}}{\beta \left( 1 + \alpha \cdot \left. \frac{C}{I} \right|_{pc} \right)} \quad (6)$$

Thus, using Equations 4 and 5, the required quality of the uplink power control command can be estimated for a particular base station from the C/I measurement on the downlink (pilot) channel,  $\left. \frac{C}{I} \right|_{pilot}$ , the known downlink output power level  $P_{pilot}$  of that

base station, and the required output power  $P_{pc}$  of the uplink power control commands.

- 5 According to an exemplary embodiment, the required output power  $P_{pc}$  may be derived from several C/I measurements and known downlink output power levels averaged over time. The output power offset between the uplink power control command and the downlink information can then be calculated as follows:

$$\text{output power offset} = P_{pc} - P_{DL \text{ information}} \quad (7)$$

- 10 where  $P_{DL \text{ information}}$  is the known output power for the downlink information bits averaged over time, which may be kept track of, for example, at the base station.

- Note that  $\alpha$  is unknown. Further,  $\alpha$  is dependent on the environment as well as the distance between the remote station and the base station. However, it should be possible to estimate  $\alpha$  quite accurately, especially during handover, since this is likely to occur far from the base stations. It should also be noted that for most environments and  
15 most services, the following is true:

$$\alpha \left. \frac{C}{I} \right|_{pc} \ll 1 \quad (8)$$

Thus, a less than accurate estimate for  $\alpha$  will not significantly affect the calculation of the required quality of the uplink power control command.

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FIG. 3B illustrates a method for adjusting an output power offset between an uplink power control command and downlink information according to a second embodiment. The method begins at step 300 at which a determination is made whether the remote station is in macrodiversity. This determination can be made, e.g., by  
5 determining whether the remote station has requested another traffic channel from the network. If the remote station is not in macrodiversity, the offset between the output power of the uplink power control command and the downlink information can be set to a predetermined level at step 315. Alternately, the output power offset can be unadjusted. From step 315, the method returns to step 300. If the remote station is in macrodiversity,  
10 a characteristic of transmitted and/or received signals for each base station is determined at step 330. Then, at step 340, the required quality for the uplink power control command is calculated for each base station. At step 350, the output power offset between the uplink power control command and downlink information is adjusted independently for each base station, based on the calculated required quality for that base station. From step  
15 350, the process returns to step 300 and repeats.

According to the second embodiment, if the remote station is not in macrodiversity, the output power offset is set to a predetermined level or not adjusted. According to a third embodiment, the output power offset may also be adjusted when the remote station is not in macrodiversity.

20 FIG. 3C illustrates a method for adjusting the output power offset between an uplink power control command and downlink information according to a third embodiment. This method is the same as that shown in FIG. 3B, except that steps 300 and 315 are eliminated. According to this embodiment, the same steps 330-350 are carried out whether or not the remote station is in macrodiversity. That is, a characteristic  
25 of the signals is determined, the required quality for the uplink power control command is calculated, and the output power offset between the uplink power control command and downlink information is adjusted for the base station from which the remote station receives signals.

According to exemplary embodiments of the invention, the output power offset  
30 between uplink power control commands and downlink information is adjusted to protect

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the uplink power control commands, i.e., to ensure that the uplink power control commands have a quality that is close to the required quality. Since the mobile station is likely to measure and report C/I or gain and interference measurements for other purposes, e.g., soft handover, the proposed method will not introduce additional signaling. However, the base stations will have to keep track of their transmission powers to a certain mobile station, since the output power offset, according to an exemplary embodiment, is calculated from mobile station measurements and base station output powers averaged over the same time. When power splitting is used, the output power offset should at least be updated at the same time that the power split algorithm alters the downlink information output powers. By introducing extra signaling, the mobile station can measure and report the measured quality to the base stations in the power control commands and/or the downlink information. Further, if uplink measurements are used no signalling over the air interface is required.

Although the embodiments described above are directed to adjusting the energy offset between uplink power control commands and downlink information, the method according to the present invention may also be applied to other types of information which require a certain quality. In addition, although the embodiments described above are directed to macrodiversity, i.e., "soft handover", it will be appreciated that the invention is applicable to other scenarios in which multiple transmitters are used, e.g., "softer handover" (handover between sectors).

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

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What is claimed is:

1. In a communication system including at least one remote station and at least one base station, a method for adjusting an offset in output power between first and second signals that are transmitted to the remote station from the base station, the method comprising the steps of:
  - determining a characteristic of a signal;
  - calculating a required quality for transmitting the first signal based on the determined characteristic; and
  - adjusting the offset in output power between the first signal and the second signal based on the calculated required quality.
2. The method of claim 1, wherein the first signal is a power control command for controlling the power of signals transmitted from the remote station to the base station.
3. The method of claim 1, further comprising a step of determining whether the remote station receives substantially the same signal simultaneously from more than one base station, wherein if remote station receives substantially the same signal simultaneously from more than one base station, the output power offset is independently adjusted for each base station.
4. The method of claim 3, wherein if the remote station does not receive substantially the same signal simultaneously from more than one base station, the output power offset is set to a predetermined level or not adjusted.
5. The method of claim 1, wherein the step of determining a characteristic comprises measuring the gain and/or interference of a signal transmitted from the base station and received at the remote station.

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6. The method of claim 1, wherein the step of determining a characteristic comprises measuring the carrier to interference ratio of a signal transmitted from the base station and received at the remote station.

5           7. The method of claim 1, wherein the step of determining a characteristic comprises measuring the carrier to interference ratio of a signal transmitted from the remote station and received at the base station.

10           8. The method of claim 1, wherein the step of determining a characteristic comprises measuring the power of a signal transmitted from the remote station and received at the base station.

15           9. The method of claim 1, wherein the communication system is a Code Division Multiple Access (CDMA) system.

10           10. In a communication system including at least one base station and at least one remote station, a method for adjusting an output power offset between a first signal and a second signal transmitted from a base station to a remote station, the method comprising the steps of:

20           determining whether the remote station receives substantially the same signal simultaneously from more than one base station; and

              adjusting the output power offset based on whether the remote station receives substantially the same signal simultaneously from more than one base station.

25           11 The method of claim 10, wherein the first signal is a power control command for controlling the power of signals transmitted from the remote station to the base station.

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12. The method of claim 10, wherein if the remote station does not receive substantially the same signal simultaneously from more than one base station, the output power offset is set to a first level.

5           13. The method of claim 10, wherein if the remote station receives the substantially the same signal simultaneously from more than one base station, the output power offset for each base station is set to a second level.

10           14. The method of claim 10, wherein if the remote station receives substantially the same signal from more than one base station, the method further comprises the steps of:

              determining a characteristic of a signal;  
              calculating the required quality for transmitting the first signal for each base station based on the determined characteristic; and  
15           adjusting the output power offset for each base station based on the reported characteristic.

              15. The method of claim 14, wherein the step of determining a characteristic comprises measuring the gain and/or interference of a signal transmitted from the base station and received at the remote station.  
20

              16. The method of claim 14, wherein the step of determining a characteristic comprises measuring the carrier to interference ratio of a signal transmitted from the base station and received at the remote station.

25           17. The method of claim 14, wherein the step of determining a characteristic comprises measuring the carrier to interference ratio of a signal transmitted from the remote station and received at the base station.

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18. The method of claim 14, wherein the step of determining a characteristic comprises measuring the power of a signal transmitted from the remote station and received at the base station

- 5           19. The method of claim 10, wherein the communication system is a Code Division Multiple Access (CDMA) system.

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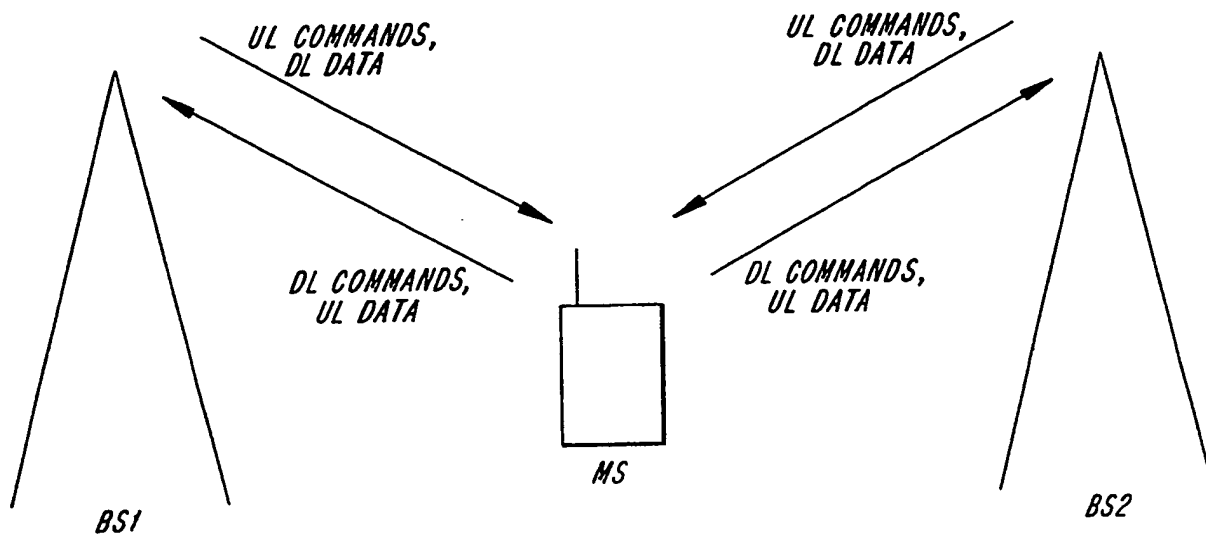


FIG. 1

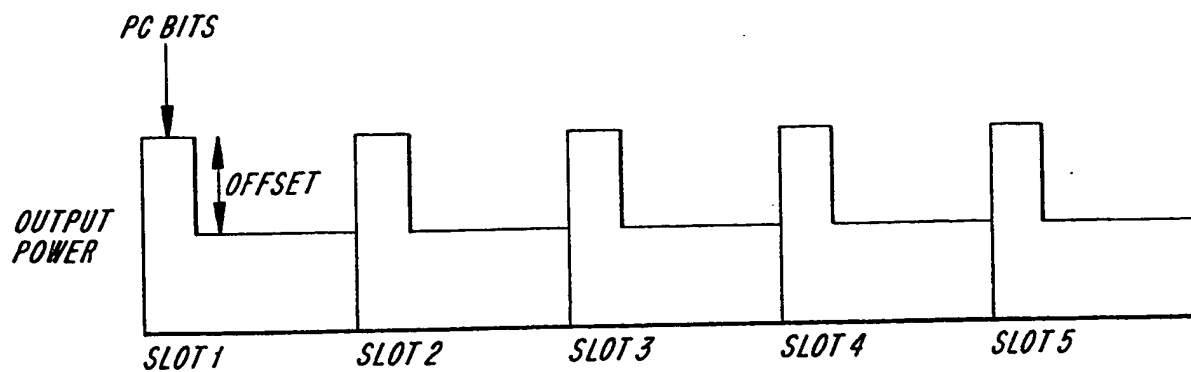
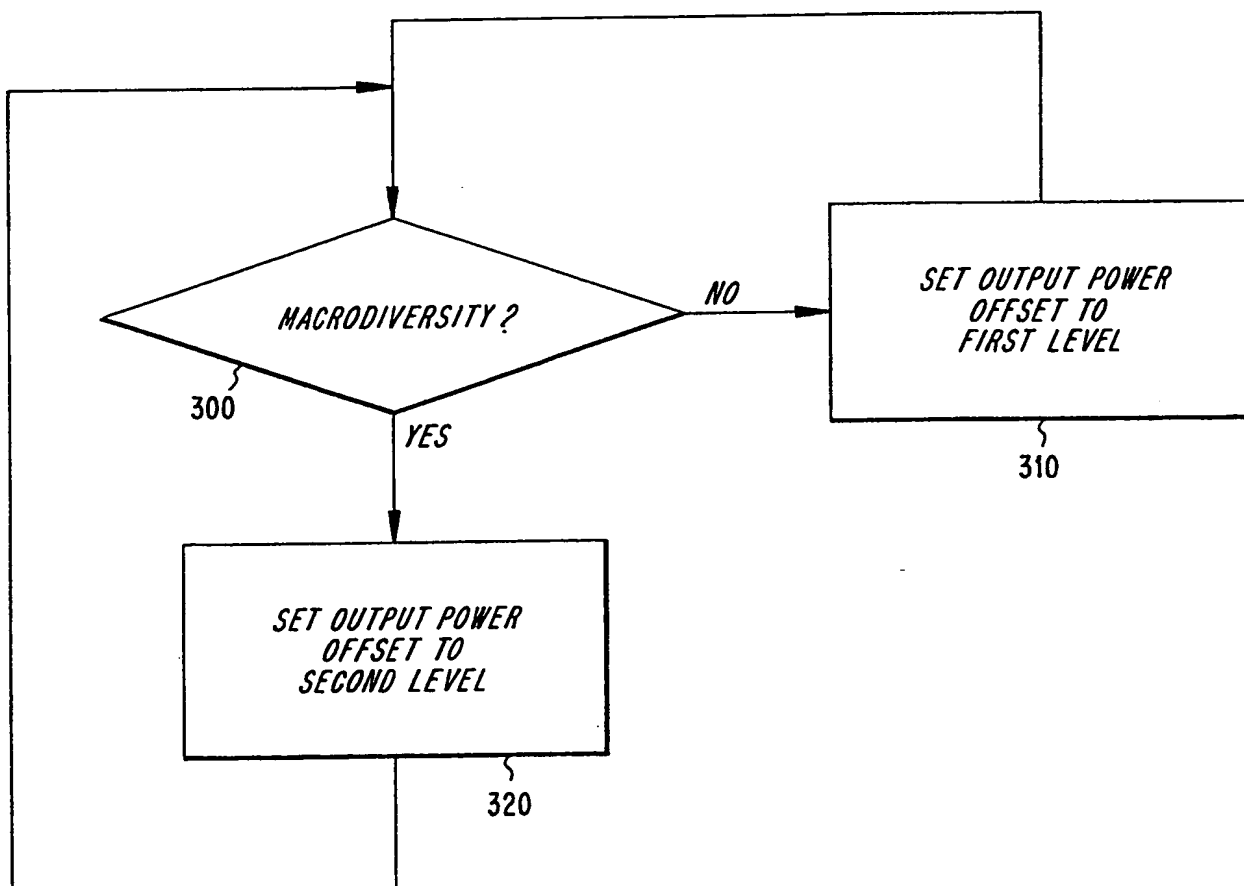


FIG. 2

FIG. 3A



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FIG. 3B

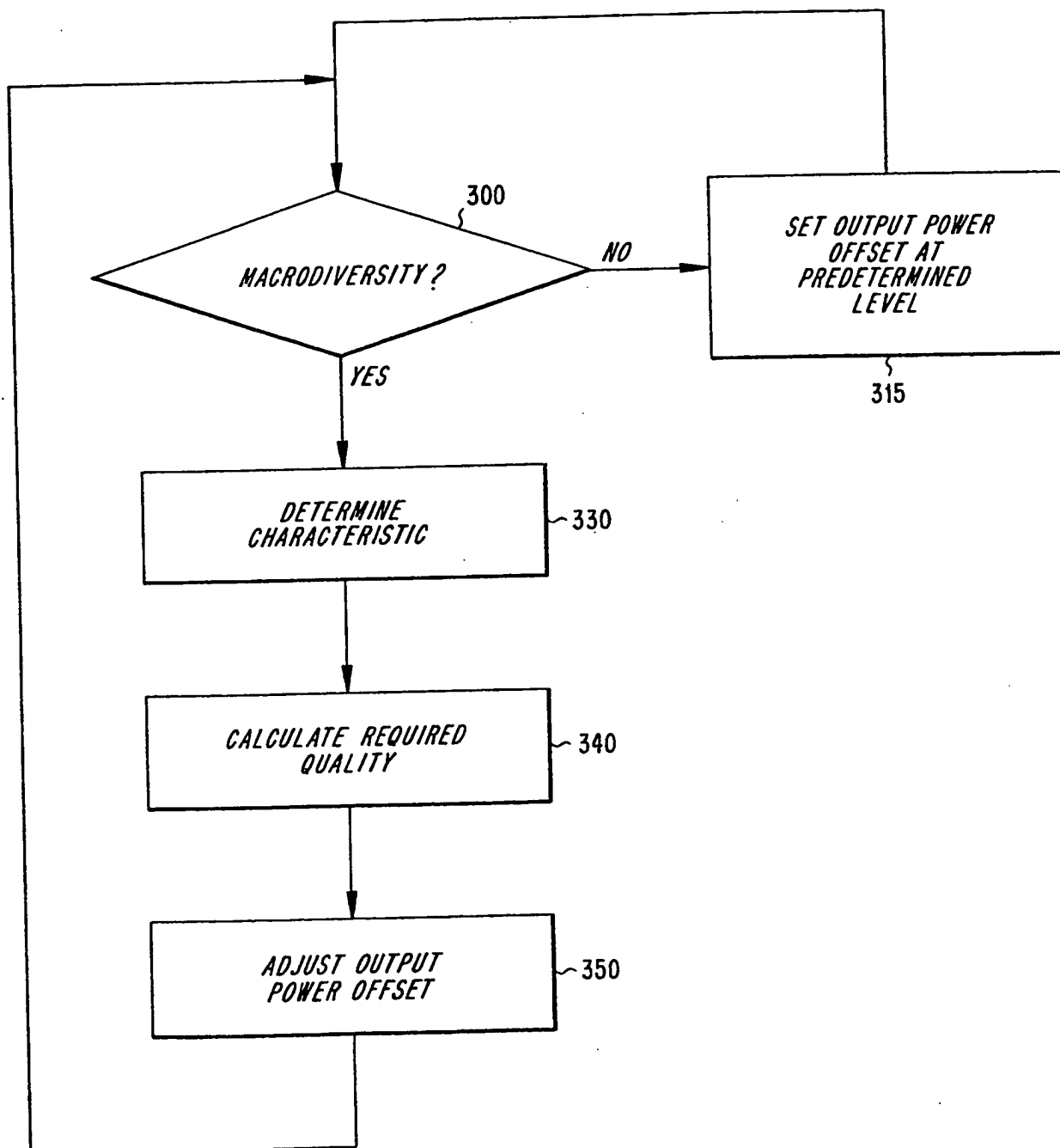
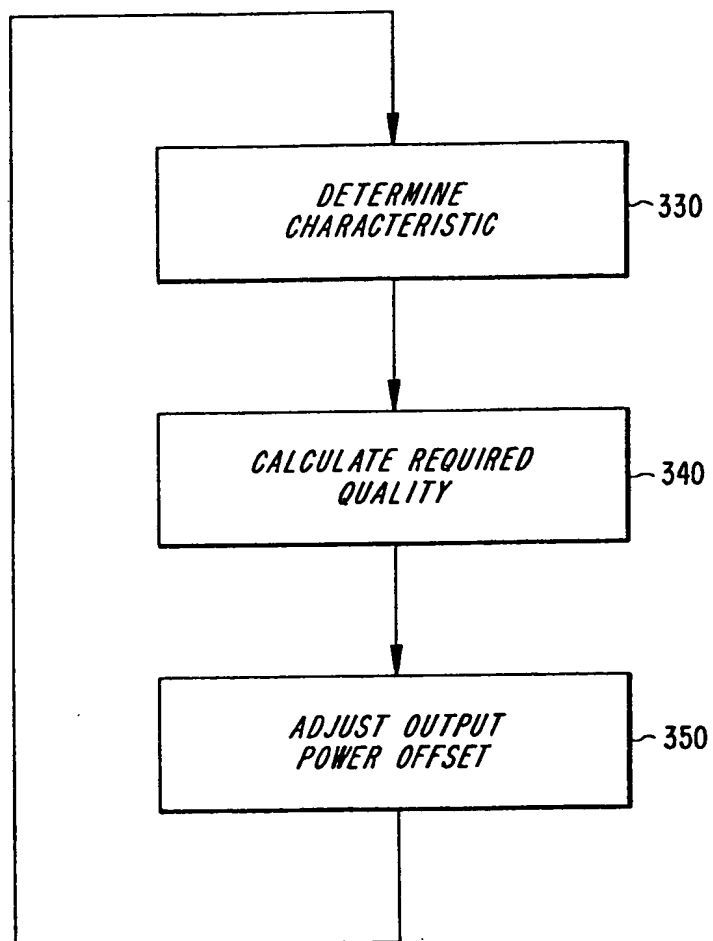


FIG. 3C



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/SE 99/00548

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 H04B7/005 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 H04B H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
|------------|--|-----------------------|
| A          | EP 0 768 804 A (NIPPON ELECTRIC CO)<br>16 April 1997 (1997-04-16)<br>* abstract *<br>column 1, line 24 - line 55<br>column 2, line 30 - column 3, line 2<br>column 4, line 12 - line 30<br>column 5, line 50 - column 6, line 29<br>figures 1,2,4<br>--- | 1,10                  |
| A          | WO 97 08911 A (HAEMAELAEINEN SEPPO ;NOKIA<br>TELECOMMUNICATIONS OY (FI); HAEKKINEN H)<br>6 March 1997 (1997-03-06)<br>* abstract *<br>page 4, line 16 - line 27<br>page 5, line 28 - page 8, line 10<br>---<br>-/--                                      | 1,10                  |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

3 August 1999

Date of mailing of the international search report

11/08/1999

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| Category * | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
|------------|---|-----------------------|
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Information on patent family members

In International Application No

PCT/SE 99/00548

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)  | Publication<br>date  |
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